NOx SCR Design for High Efficiency at High Concentration, Dust and SOx Loading

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The manufacturer of catalysts presented a difficult application for traditional SCR systems. The two process gas streams, from three calciners, varied in flowrate and concentration. One stream contained a high level of NOx, while the other had a high ammonia level. Both streams had a high inorganic dust loading, even after passing through dust collectors. The measured SOx levels were high, with even higher theoretical concentrations projected. The NO/NO_2 ratio varied, and the operating temperature increased by 160 °F from beginning to end of the batch process operating cycle. The customer required a NOx efficiency above 95% and an ammonia emission rate that required the efficiency above 99%, even including slip. Table 1 shows the design conditions.

The system design team found several pitfalls. Fluctuating flowrates and temperatures challenge the mechanical design for even distribution, for good transfer rates, and challenge the safety design in any direct-fired unit. The successful design must also handle the five special process concerns that could have led to frequent breakdown or might severely limit efficiency. First, it was necessary to preheat the streams to 400 °F before combining to avoid forming ammonium nitrate. Likewise, one would add vaporized aqueous ammonia to the process for the same reason. Second, the inlet NOx concentration was so high that dilution was necessary to minimize exothermic reaction temperature rise. SCR catalysts display a maxima point in the efficiency versus temperature curve that limits the useful temperature range. Third, after the outlet of the catalyst bed, unreacted ammonia could combine with sulfur trioxide to form ammonium bisulfate. This material would plate out in cooler regions, plugging equipment and corroding it. Fourth, the design must convey particulate materials through the unit without trapping them or eroding fragile catalyst surfaces. Fifth, feedback ammonia control had to operate without the inlet NOx measurement. The successful system will have avoided all of these pitfalls.

The design required cooperation between engineering, testing and development. Catalyst testing was necessary to guarantee efficiency. Early test data determined that at least two beds were necessary for more than 93% efficiency. The testing suggested using Econ-NOx ZX1 catalyst in the first bed. The bed would operate at higher-than-normal ammonia/NOx ratios and a slightly reduced operating temperature to SOx suppression. Excess ammonia would pass to the second bed with the reduced NOx flow. The second bed would contain lower temperature Econ-NOx ZCX1 catalyst. This bed would operate at a slightly elevated temperature, reducing NOx and scavenging ammonia to nitrogen and water. With some dilution from the required carrier air, no additional dilution was necessary. This hybrid catalyst system provided the solution to the efficiency problem. The catalysts also had a very low oxidation of SO_2 to SO_3, less than 1% at normal temperature. There was no increase in the potential for ammonium salts formation when the catalyst does not oxidize SOx. Figure 1 presents the expected performance curve for the SCR.

Preliminary engineering then addressed particulate handling and ammonium salt prevention. The fluidized bed of non-precious metal zeolite of the Econ-NOx ™ Selective Catalytic Reduction System offered good particulate handling characteristics. Several dirty applications used the Econ-Abator® Catalytic Oxidizer version without catalyst blinding or mechanical flow problems from particulate loading up to 0.03 gr/DSCF. This formed the basis for the Econ-NOx™ SCR version, so that would perform without particulate problems also. A self-recuperative heat exchanger with two separate inlets but one outlet preheated the process streams to more than 400 °F before mixing. Preventing a stack temperature below 450 °F limited the overall efficiency of this exchanger to 50%. The aqueous ammonia vaporizer used preheated carrier air from an economiser inserted between the burner and catalyst. The ammonia flow controller varied only ammonia flow while carrier air rate was constant. This minimized the possible maldistribution from the ammonia injection grid with such a large ammonia turndown. Figure 2 is a process flow scheme of the system.

As of late March 1997, installation of the system was complete. The process development will have begun on site immediately after start-up, and will have continued through the setting the process control algorithm. We have not yet begun start-up, but will do so shortly. The following four steps summarize the proposed development plan. We test for flow maldistribution first, then for ammonia maldistribution. We optimize temperature and ammonia/NOx ratio at one setting of flow and composition for NOx efficiency and ammonia efficiency. We repeat this again for each of two or three other settings of flow and composition. This results in an algorithm yielding temperature and ammonia/NOx ratio at other flows and compositions. The algorithm minimizes NOx and ammonia emissions based upon the measured outlet concentrations and flowrate.

The manufacturer supplied a fluidized bed of zeolite catalyst with specially designed equipment to handle a difficult application for traditional SCR systems. Warranted emissions required 95+% NOx efficiency and 99+% ammonia efficiency. Measured actual emissions will soon be available.

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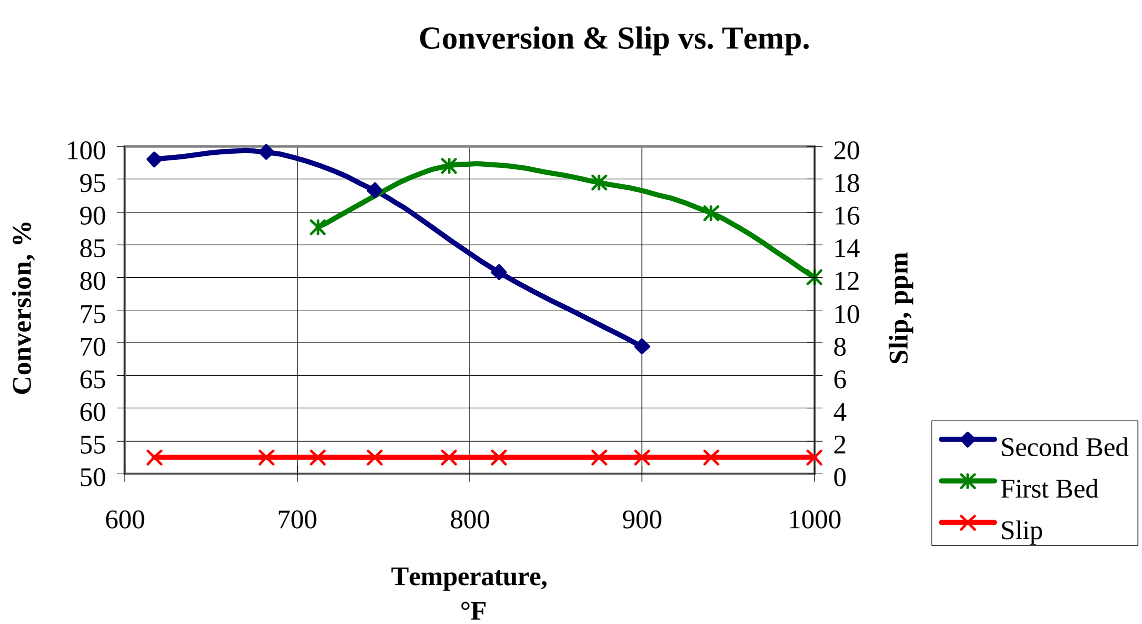
TABLE 1
Design Conditions

Condition	Range	Variability
Flowrate, SCFM	3,220 to 8,374	2.6 : 1
NOx rate, lb/hr	10 to 250	25 : 1
NH_3 rate, lb/hr	6 to 55	9.2 : 1
Temperature, °F	176 to 338	
Dust Loading, gr/DSCF	up to 0.010	
NO / NOx ratio	0.33 to 0.70	2.1 : 1
SOx rate, ppm v	35 to 466	13.3 : 1
SO_3 / SOx ratio	up to 0.10	

FIGURE 1
Performance Curve



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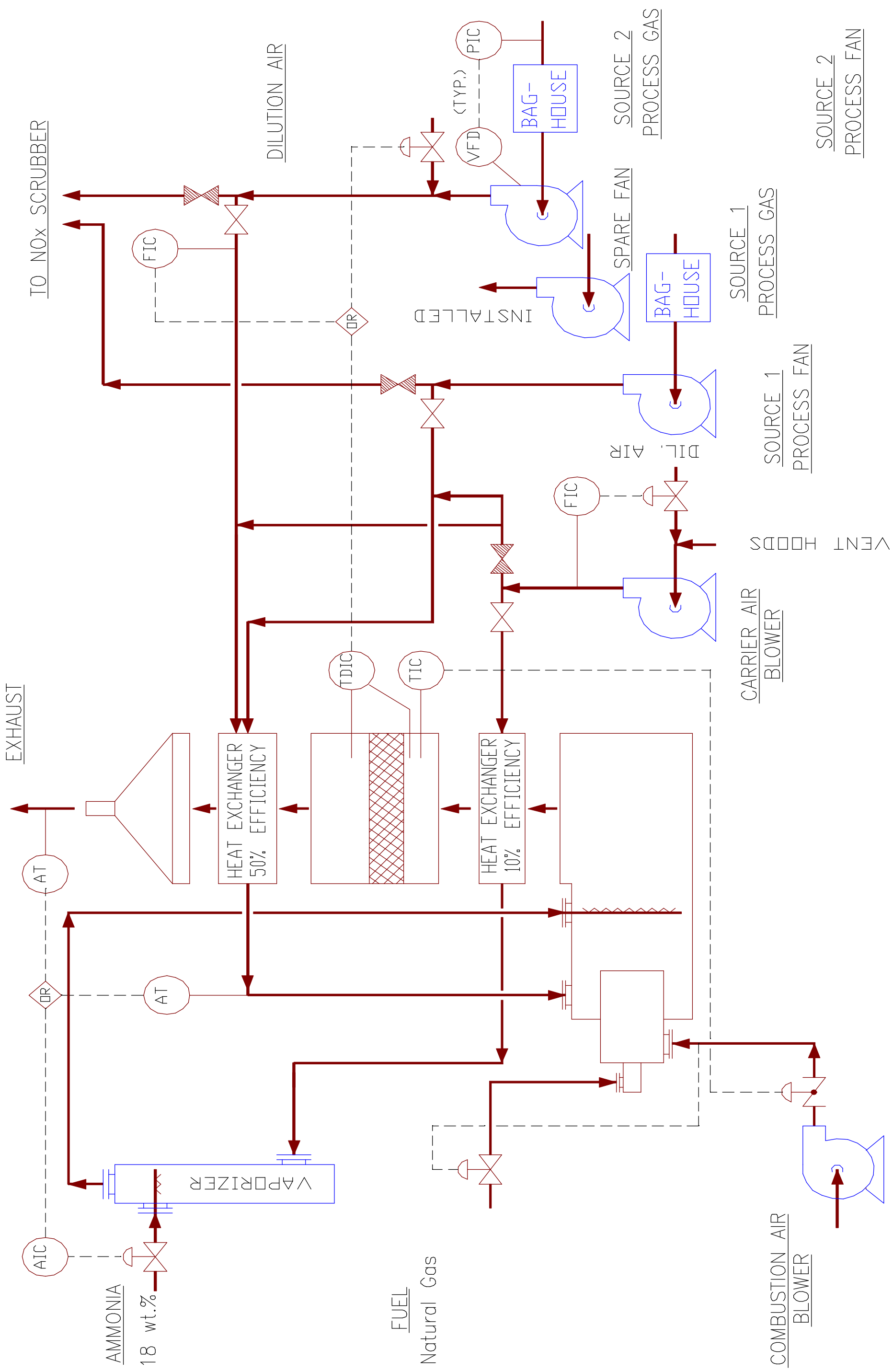

Figure 2
PROCESS FLOW SCHEME
ECON-NOx TM SELECTIVE CATALYTIC REDUCTION SYSTEM

CATALYST ENTRY TEMPERATURE SHOWN IS BEST ESTIMATE AND MAY VARY WITH ACTUAL OPERATING CONDITIONS AND REQUIRED CONVERSION EFFICIENCY.